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(54) ORGANIC SOLID WASTE TO METHANE FUEL CONVERSION FOR SPACECRAFT

(57) A system includes an oxidative combustion reactor (104) configured to receive solid organic waste and 02, and to output a combined stream of H2O and CO2. A separator (106) is configured to receive the combined stream of H2O and CO2 from the combustion reactor and to separately output a stream of CO2 and a stream of H2O. A Sabatier reactor (108) is operatively connected to receive CO2 from the separator and to receive H2 from an H2 source, and to output gaseous CH4.

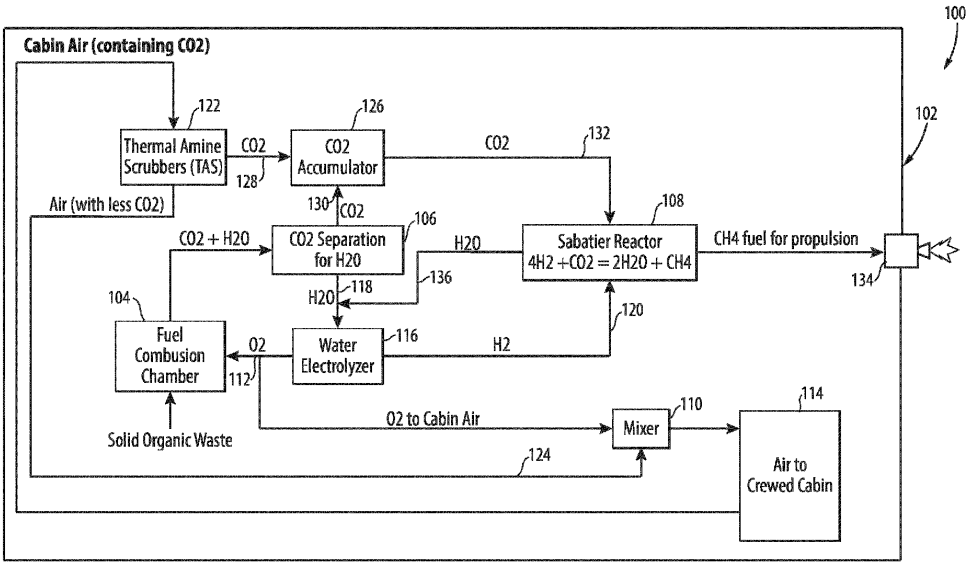

Fig. 1

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Description

BACKGROUND

1. Field

[0001] The present disclosure relates to fuel generation, and more particularly to solid organic waste to methane fuel generation for use in spacecraft propulsion such as for deep space missions such as those for the Artemis Program for deep space exploration and for commercial spacecraft such as the Orbital Reef.

2. Description of Related Art

[0002] Deep space missions involve distances from Earth to the Moon, Mars, and beyond. Crewed space missions to the Moon take about three days travel time from Earth to the Moon. Space missions to Mars take about seven months travel time from Earth to Mars. Due to long travel times, supplies of fuel to propel and maneuver spacecraft is needed for support of deep space missions.

[0003] The conventional techniques have been considered satisfactory for their intended purpose. However, there is an ever-present need for improved systems and methods for fuel supplies for deep space missions and the like. This disclosure provides a solution for this need.

SUMMARY

[0004] A system includes a combustion reactor configured to receive solid organic waste and O_2, and to output a combined stream of H_2O and CO_2. A separator is configured to receive the combined stream of H_2O and CO_2 from the combustion reactor and to separately output a stream of CO_2 and a stream of H_2O. A Sabatier reactor is operatively connected to receive CO_2 from the separator and to receive H_2 from an H_2 source, and to output CH_4.

[0005] A mixer can be operatively connected to receive a portion of the O_2 diverted from a supply line supplying the O_2 to the combustion reactor, and to receive CO_2 scrubbed air, and to output a mixture of the diverted O_2 and the CO_2 scrubbed air.

[0006] A water electrolyzer can be operatively connected to receive H_2O from the separator through a water supply line, to output the H_2 to the Sabatier Reactor through an H_2 supply line, and to output the O_2 to the supply line supplying the O_2 to the combustion reactor and to the mixer, for oxidizing the solid organic waste with pure O_2 in the combustion reactor. A thermal amine scrubber (TAS) can be configured to receive cabin air that includes CO_2 and to output the CO_2 scrubbed air to the mixer in a scrubbed air line.

[0007] A CO_2 accumulator can be connected to a first CO_2 line to receive CO_2 from the TAS. The CO_2 accumulator can be connected to a second CO_2 line to receive CO_2 from the separator. The CO_2 accumulator can be connected to a third CO_2 line to supply CO_2 from the CO_2 accumulator to the Sabatier reactor.

[0008] A spacecraft can include a thruster operatively connected to receive CH_4 from the Sabatier reactor for combustion to generate thrust. The spacecraft can include a cabin configured to receive O_2 enriched air from the mixer and to supply CO_2 to the TAS for scrubbing.

[0009] A method of producing fuel includes combining CO_2 from a spacecraft cabin and from solid organic waste, and supplying the CO_2 to a Sabatier reactor to produce CH_4 fuel. The method includes generating H_2 and supplying it to the Sabatier reactor for use in generating the CH_4 fuel, wherein generating H_2 includes producing O_2, at least some of which is supplied to the spacecraft cabin for life support.

[0010] The method can include mixing CO_2 scrubbed air with the O_2 which is supplied to the cabin for life support. The CO_2 from solid organic waste can be produced by reacting the organic waste with O_2. Reacting the organic waste with O_2 can include combusting the organic waste and O_2 into combustion products including CO_2 and H_2O.

[0011] The method can include separating CO_2 from the combustion products for use in the Sabatier Reactor and separating H_2O from the combustion products. The method can include electrolyzing the H_2O from the combustion products into O_2 and H_2 and supplying the H_2 to the Sabatier reactor. The method can include recycling H_2O from the Sabatier reactor to be electrolyzed. The method can include scrubbing CO_2 from the spacecraft cabin for use in the Sabatier reactor. The method can include combusting the CH_4 in a thruster of the spacecraft.

[0012] These and other features of the systems and methods of the subject disclosure will become more readily apparent to those skilled in the art from the following detailed description of the preferred embodiments taken in conjunction with the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] So that those skilled in the art to which the subject disclosure appertains will readily understand how to make and use the devices and methods of the subject disclosure without undue experimentation, preferred embodiments thereof will be described in detail herein below with reference to certain figures, wherein:

Fig. 1 is a schematic view of an embodiment of a system constructed in accordance with the present disclosure, showing system components used to produce fuel from solid organic waste.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0014] Reference will now be made to the drawings wherein like reference numerals identify similar structural

features or aspects of the subject disclosure. For purposes of explanation and illustration, and not limitation, a partial view of an embodiment of a system in accordance with the disclosure is shown in Fig. 1 and is designated generally by reference character 100. The systems and methods described herein can be used to produce gaseous fuel from solid organic waste, such as leftover food from the crew members and other sources of solid organic matter, for use to propel the spacecraft during deep space missions.

[0015] The system 100 can include or be incorporated in a crewed spacecraft 102. The system includes an oxidative combustion reactor 104 configured to receive solid organic waste and O_2, and to output a combined stream of H_2O and CO_2, as indicated by the arrows pointing into and out of the reactor 104 in Fig. 1. A separator 106 is configured to receive the combined stream of H_2O and CO_2 from the combustion reactor 104 and to separately output a stream of CO_2 and a stream of H_2O, as indicated by the arrows into and out of the separator 106 in Fig. 1. A Sabatier reactor 108 is operatively connected to receive CO_2 from the separator 106 and to receive H_2 from an H_2 source, e.g. the water electrolyzer described below, and to output gaseous CH_4, as indicated by the arrows into and out of the reactor 108 in Fig. 1.

[0016] A mixer 110 is operatively connected to receive a portion of the O_2 diverted from a supply line 112 supplying the O_2 to the combustion reactor 104, and to receive metabolic CO_2 scrubbed air, e.g. from the thermal amine scrubbers (TAS) described below, and to output a mixture of the diverted O_2 and the metabolic CO_2 scrubbed air, e.g. to the crewed cabin 114 for breathing air for the spacecraft crew members.

[0017] A water electrolyzer 116 is operatively connected to receive H_2O from the separator 106 through a water supply line 118, to output the H_2 gas to the Sabatier Reactor 108 through an H_2 supply line 120, and to output the O_2 to the supply line 112 supplying the O_2 to the oxidative combustion reactor 104 and to the mixer 110, e.g., for oxidizing the solid organic waste with pure O_2 in the oxidative combustion reactor. A thermal amine scrubber (TAS) 122 is configured to receive cabin air that includes metabolic CO_2 and to output the CO_2 scrubbed air to the O_2/air mixer 110 in a scrubbed air line 124.

[0018] A CO_2 accumulator 126 is connected to a first CO_2 line 128 to receive CO_2 from the TAS 122. The CO_2 accumulator 126 is connected to a second CO_2 line 130 to receive CO_2 from the separator 106. The CO_2 accumulator 126 is connected to a third CO_2 line 132 to supply CO_2 from the CO_2 accumulator 126 to the Sabatier reactor 108.

[0019] The spacecraft 102 includes a thruster 134 operatively connected to receive CH_4 from the Sabatier reactor 108, as indicated by the arrow out of the Sabatier reactor 108 in Fig. 1, for combustion to generate thrust. The thruster 134 can be a propulsion thruster, a maneuvering jet, or the like. The spacecraft 102 includes a cabin 114 configured to receive O_2 enriched air from the O_2/air mixer 110 and to supply CO_2 to the TAS 122 for scrubbing.

[0020] A method of producing fuel includes combining CO_2 from a spacecraft crew cabin, e.g. cabin 114, and from solid organic waste, and supplying the CO_2 to a Sabatier reactor, e.g. Sabatier reactor 108, to produce CH_4 fuel. The method includes generating H_2 and supplying it to the Sabatier reactor for use in generating the gaseous CH_4 fuel, wherein generating H_2 includes producing O_2, at least some of which is supplied to the spacecraft crew cabin for life support.

[0021] The method includes mixing metabolic CO_2 scrubbed air with the O_2 which is supplied to the cabin for life support. The CO_2 from solid organic waste oxidative combustion is produced by reacting the organic waste with O_2, e.g. in the reactor 104. Reacting the organic waste with O_2 includes combusting the organic waste and O_2 into combustion products including gaseous CO_2 and water vapor H_2O.

[0022] The method includes separating CO_2 from the oxidative combustion products for use in the Sabatier Reactor and separating H_2O from the combustion products, e.g., in a separator 106. The method includes electrolyzing the H_2O from the combustion products into O_2 and H_2 and supplying the H_2 to the Sabatier reactor, e.g. using an electrolyzer 116. The method includes recycling H_2O from the Sabatier reactor to be electrolyzed, e.g. using the water recycle line 136 feeding into line 118. The method includes scrubbing CO_2 from the spacecraft crew cabin for use in the Sabatier reactor, e.g. using the TAS 122. The method includes combusting the CH_4 in a thruster, e.g., thruster 134, of the spacecraft. Some of the O_2 generated from the water electrolyzer 116 can be used to combust CH_4 in the thruster to propel the spacecraft 102.

[0023] The methods and systems of the present disclosure, as described above and shown in the drawings, provide for production of fuel from solid organic waste such as for use during deep space missions. While the apparatus and methods of the subject disclosure have been shown and described with reference to preferred embodiments, those skilled in the art will readily appreciate that changes and/or modifications may be made thereto without departing from the scope of the subject disclosure.

Claims

1. A system comprising:

a combustion reactor (104) configured to receive solid organic waste and O_2, and to output a combined stream of H_2O and CO_2;

a separator (106) configured to receive the combined gaseous stream of H_2O and CO_2 from the oxidative combustion reactor and to separately output a stream of CO_2 and a stream of H_2O; and

a Sabatier reactor (108) operatively connected to receive CO_2 from the separator and to receive H_2 from an H_2 source, and to output CH_4.

2. The system as recited in claim 1, further comprising: an O_2/air mixer (110) operatively connected to receive a portion of the O_2 diverted from a supply line (112) supplying the O_2 to the oxidative combustion reactor (104), and to receive metabolic CO_2 scrubbed air, and to output a mixture of the diverted O_2 and the metabolic CO_2 scrubbed air.

3. The system as recited in claim 1 or 2, further comprising a water electrolyzer (116) operatively connected to

receive H_2O from the separator (106) through a water supply line (118);
output the H_2 to the Sabatier Reactor (108) through an H_2 supply line (120); and
output the O_2 to the supply line (112) supplying the O_2 to the combustion reactor and to the mixer (110), for oxidizing the solid organic waste with pure O_2 in the combustion reactor (104).

4. The system as recited in claim 1, 2 or 3, further comprising:
a thermal amine scrubber, TAS, (122) configured to receive cabin air that includes metabolic CO_2 and to output the metabolic CO_2 scrubbed air to the mixer (110) in a scrubbed air line (124).

5. The system as recited in claim 4, further comprising: a CO_2 accumulator (126) connected to a first CO_2 line (128) to receive CO_2 from the TAS (122), wherein the CO_2 accumulator is connected to a second CO_2 line (130) to receive CO_2 from the separator (106), and wherein the CO_2 accumulator is connected to a third CO_2 line (132) to supply CO_2 from the CO_2 accumulator to the Sabatier reactor (108).

6. The system as recited in claim 4 or 5, further comprising:
a spacecraft (102) including:

a thruster (134) operatively connected to receive CH_4 from the Sabatier reactor (108) for combustion to generate thrust to propel the spacecraft; and
a cabin (114) configured to receive O_2 enriched air from the mixer (110) and to supply CO_2 to the TAS (122) for scrubbing.

7. A method of producing fuel comprising:

combining the metabolic CO_2 from a spacecraft crew cabin and from solid organic waste, and supplying the CO_2 to a Sabatier reactor to produce gaseous CH_4 fuel; and
generating H_2 and supplying it to the Sabatier reactor for use in generating the gaseous CH_4 fuel, wherein generating H_2 includes producing O_2, at least some of which is supplied to the spacecraft crew cabin for life support.

8. The method as recited in claim 7, further comprising mixing metabolic CO_2 scrubbed air with the O_2 which is supplied to the crew cabin for life support.

9. The method as recited in claim 7 or 8, wherein the CO_2 from solid organic waste is produced by reacting the solid organic waste with O_2.

10. The method as recited in claim 9, wherein reacting the solid organic waste with O_2 includes combusting the organic waste and O_2 into combustion products including CO_2 and H_2O.

11. The method as recited in claim 10, further comprising separating CO_2 from the combustion products for use as a feedstock in the Sabatier Reactor and separating H_2O from the combustion products.

12. The method as recited in claim 11, further comprising electrolyzing the H_2O from the combustion products into O_2 and H_2 and supplying the H_2 as a feedstock to the Sabatier reactor.

13. The method as recited in claim 12, further comprising recycling H_2O from the Sabatier reactor to be electrolyzed.

14. The method as recited in any of claims 7 to 13, further comprising scrubbing metabolic CO_2 from the spacecraft crew cabin for use in the Sabatier reactor.

15. The method as recited in claim 14, further comprising combusting the gaseous CH_4 in a thruster of the spacecraft.

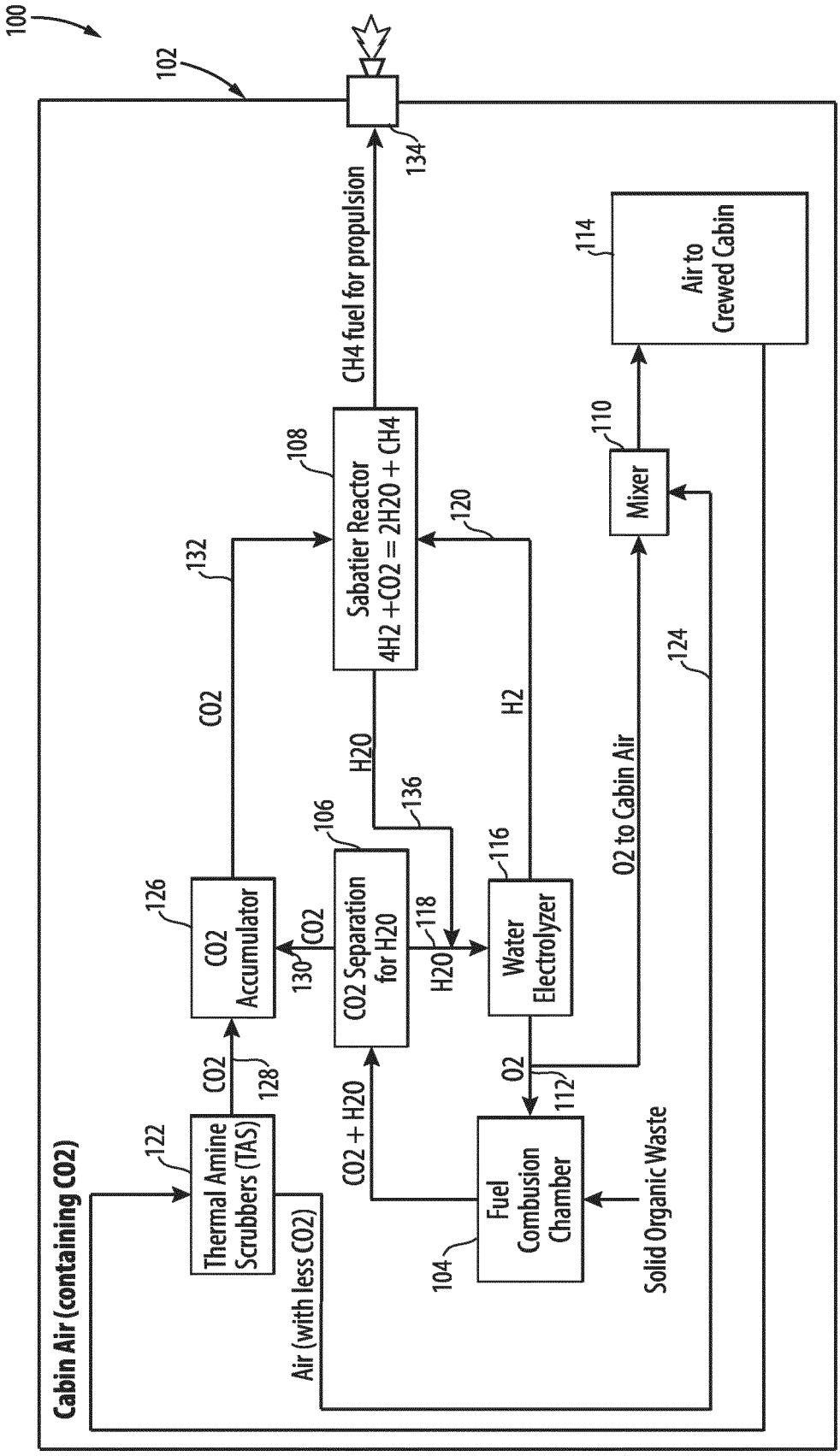
100
102
134
CH4 fuel for propulsion
114
Air to Crewed Cabin
110
Mixer
108
Sabatier Reactor
4H2 +CO2 = 2H2O + CH4
120
132
CO2
H2O
136
H2
124
O2 to Cabin Air
106
126
CO2 Accumulator
CO2
CO2 Separation for H2O
118
116
Water Electrolyzer
130
H2O
CO2
128
O2
112
CO2 + H2O
122
Thermal Amine Scrubbers (TAS)
Fuel Combusion Chamber
104
Solid Organic Waste
Air (with less CO2)
Cabin Air (containing CO2)

Fig. 1

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EUROPEAN SEARCH REPORT

Application Number
EP 23 20 2531

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	GANZER B ET AL: "Integration of an algal photobioreactor into an environmental control and life support system of a space station", ACTA ASTRONAUTICA, PERGAMON PRESS, ELMSFORD, GB, vol. 65, no. 1-2, 1 July 2009 (2009-07-01), pages 248-261, XP026127307, ISSN: 0094-5765, DOI: 10.1016/J.ACTAASTRO.2009.01.071 [retrieved on 2009-03-24] * page 248 - page 249 * * figure 1; table 1 *	1-15	INV. C10L3/08 C07C1/12 C07C9/04 B01D53/14 C25B1/02
X	KR 2021 0125633 A (KOREA INST ENERGY RES [KR]) 19 October 2021 (2021-10-19) * paragraphs [0001], [0043] - [0082], [0104], [0118] * * claims; figures 1, 2 *	1	
A	WO 2020/203087 A1 (IHI CORP [JP]) 8 October 2020 (2020-10-08) * paragraphs [0001], [0021] - [0043] * * claims; figure 1 *	1-15	TECHNICAL FIELDS SEARCHED (IPC) C10L C07C B01D C25B B64G

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	8 February 2024	Keipert, Olaf

CATEGORY OF CITED DOCUMENTS

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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 23 20 2531

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08-02-2024

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